

**PHASE AND GAIN RESPONSE OF A
CLOSED-LOOP-CONTROLLED HIGH VOLTAGE
DC-DC CONVERTER AT CRYOGENIC
TEMPERATURES**

Test Report

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Background

The phase and gain response of a 1 kW, 80-110V/500V closed-loop-controlled high voltage full-bridge dc-dc converter was evaluated at room temperature and at various temperatures down to -185 °C. The converter design was based on that of a beam power supply for a space electric propulsion system [1], with the added capability of being able to operate over a very wide low temperature range. The schematic of the full-bridge dc-dc converter is shown in Figure 1 and its control circuit is shown in Figure 2. This cryogenic beam supply was previously tested in terms of efficiency, output voltage regulation, switching behavior and transient load testing [2,3]. Recent availability of a Venable Frequency Response System has made phase and gain response testing of the supply a reality.

Test Setup

Testing of the cryogenic beam supply was performed in a liquid nitrogen cooled chamber manufactured by SUN Systems. A Venable Frequency Response System was used to measure phase and gain response over a frequency range of 10 Hz to 1 MHz. Response measurements were recorded at chamber temperatures of 25 °C, -55 °C, -100 °C, -150 °C and -185 °C. Due to limited availability of the frequency response system, initial testing was limited to a single operating point of 100V input voltage, 500V output voltage and a 600Ω load (half load \approx 415W).

Results and Discussion

The closed-loop controller as shown in Figure 2 was constructed from metal film resistors, solid tantalum, npo ceramic and mica capacitors, as well as, CMOS (timer, logic and operational amplifier) devices. The controller utilized a Type I compensation network as defined in [4]. Previous testing utilized a 0.01μF compensation capacitor. After first cut response measurements showed a phase margin of approximately 45° and a gain margin of 14 dB at 25°C, additional compensation was added by utilizing a 0.02μF compensation capacitor. Response measurements for this configuration showed a phase margin of approximately 60° and a gain margin of 30 dB at 25 °C. Table 1 lists the measured phase and gain margins of the controller at each test temperature. As temperature was decreased to -100 °C both phase and gain margins were reduced to their minimum values of 45° and 16 dB, respectively. As temperature was furthered decreased down to -185 °C the phase and gain margins returned to values close to those obtained at 25 °C. At all temperatures the controller maintains adequate phase and gain margins for controller stability.

Table 1. Measured phase and gain margins of the controller at various test temperatures.

Temperature (°C)	Phase Margin (°)	Gain Margin (dB)
25	60	30
-55	60	27
-100	45	16
-150	48	17
-185	53	35

The phase and gain vs. frequency plots for the controller at test temperatures of 25 °C and -185 °C are shown in Figures 3 and 4, respectively.

Conclusion

A 1 kW 80-110V/550V closed-loop controlled full-bridge dc-dc converter, designed to operate from 25 °C to -185 °C using commercially available components, was evaluated in terms of its frequency response over the same temperature range. Testing was performed at a single nominal operating point of 100V input voltage, 500V output voltage and a 600Ω load (half load \approx 415W). Phase and gain response measurements were made over a frequency range of 10 Hz to 1 MHz. The converter's phase margin varied from a maximum of 60° at 25 °C to a minimum of 45° at -100 °C and the gain margin varied from a maximum of 35 dB at -185 °C to a minimum of 16 dB at -100 °C. Measured phase and gain margins at -185 °C were similar to those measured at 25 °C. At all temperatures the controller maintains adequate phase and gain margins for controller stability. The results from this work indicate that control circuits can be designed and operated at very low temperatures well beyond normal operating temperatures.

References

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Acknowledgments

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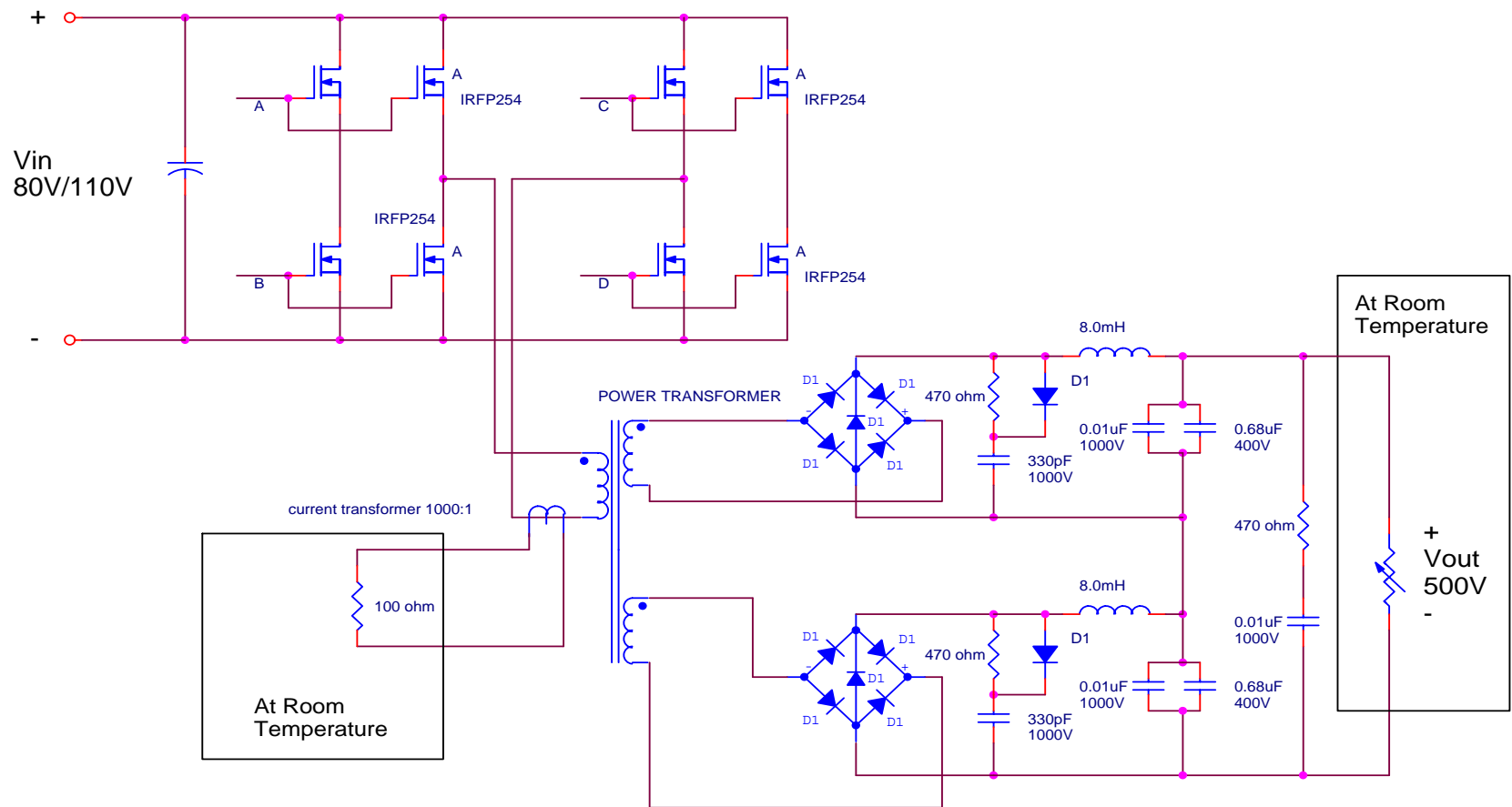


Figure 1. Full-Bridge DC-DC Cryogenic Beam Supply.

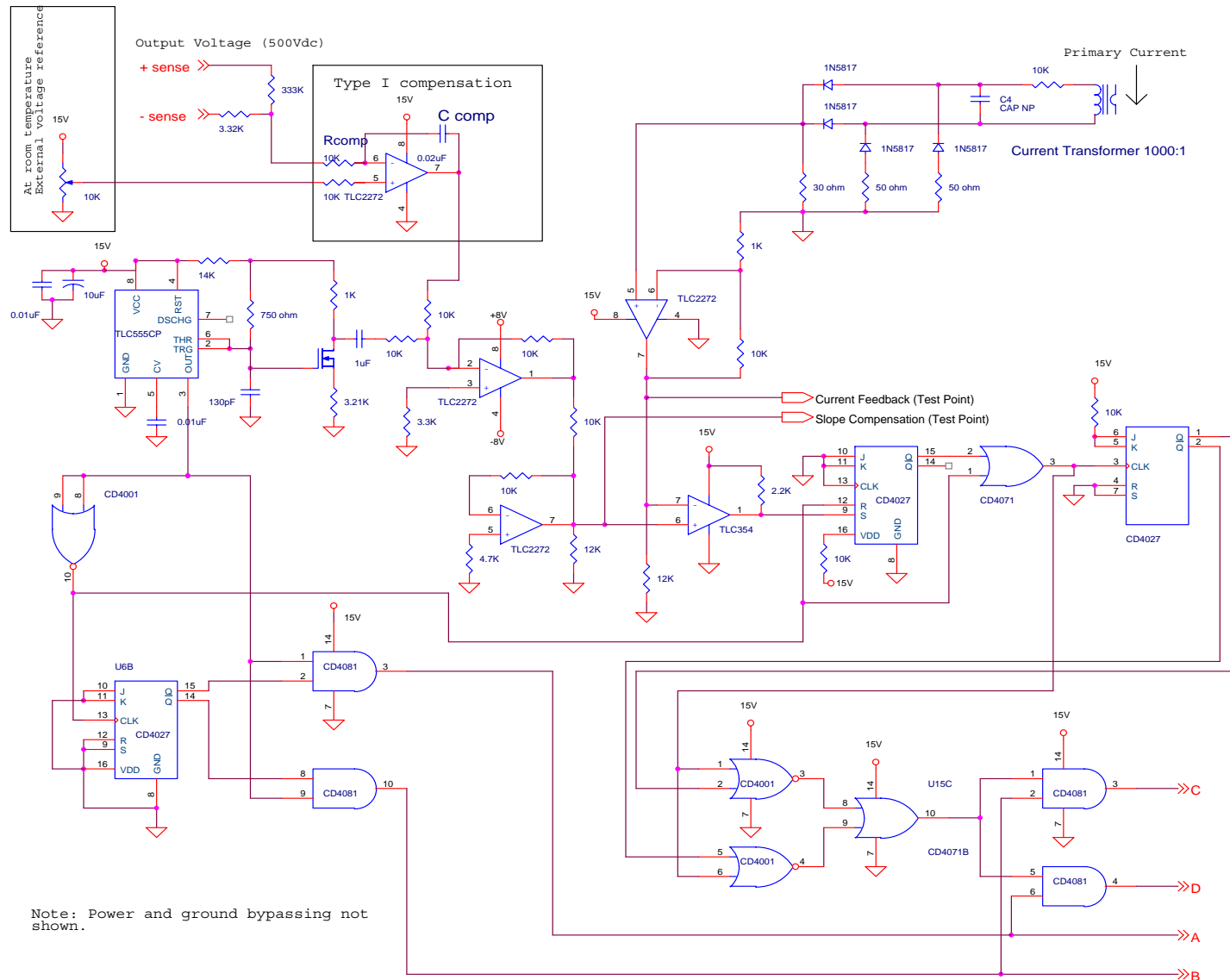


Figure 2. Closed-loop controller.

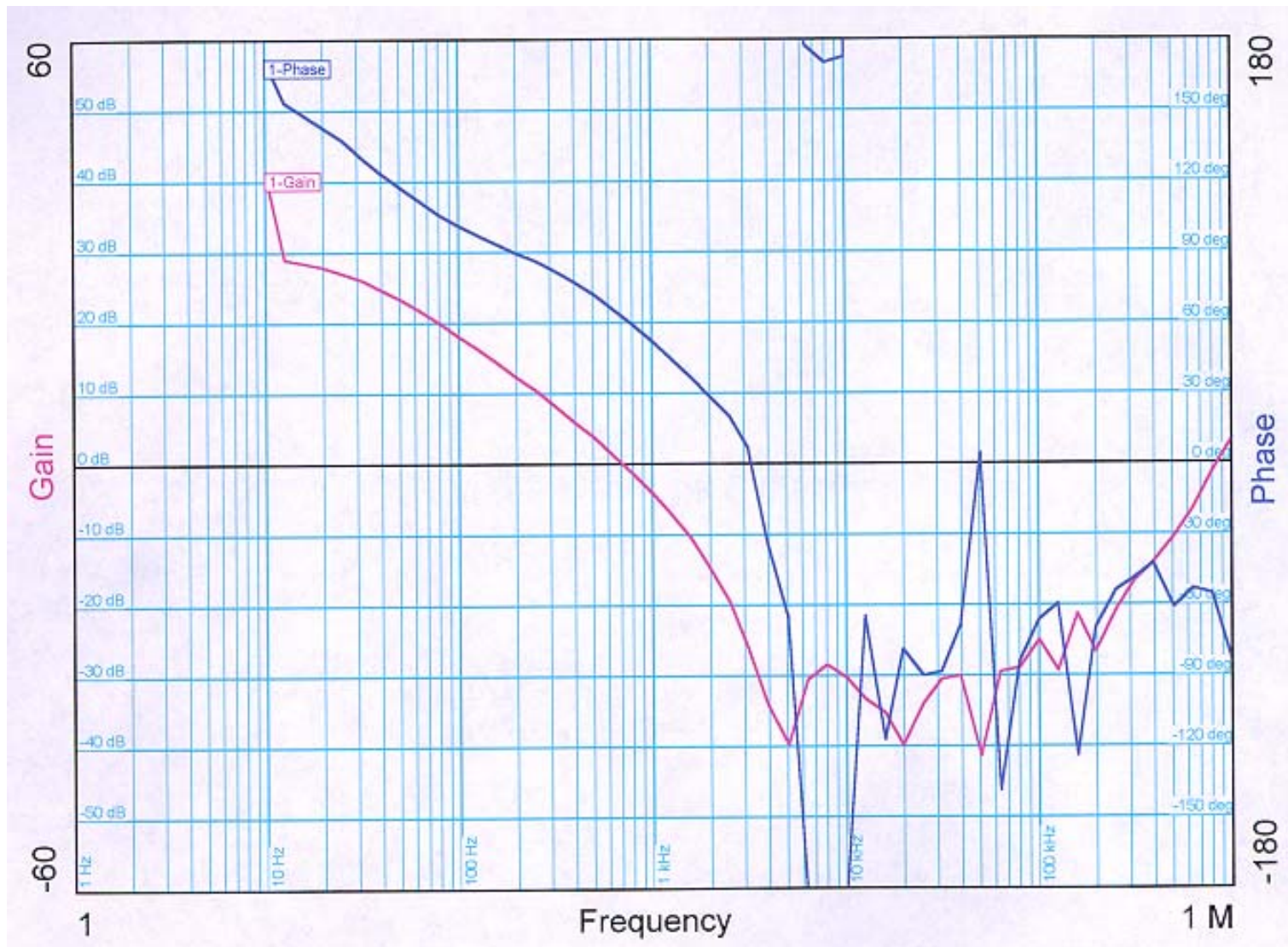


Figure 3. Phase and gain response vs. frequency of the controller at 25 °C.

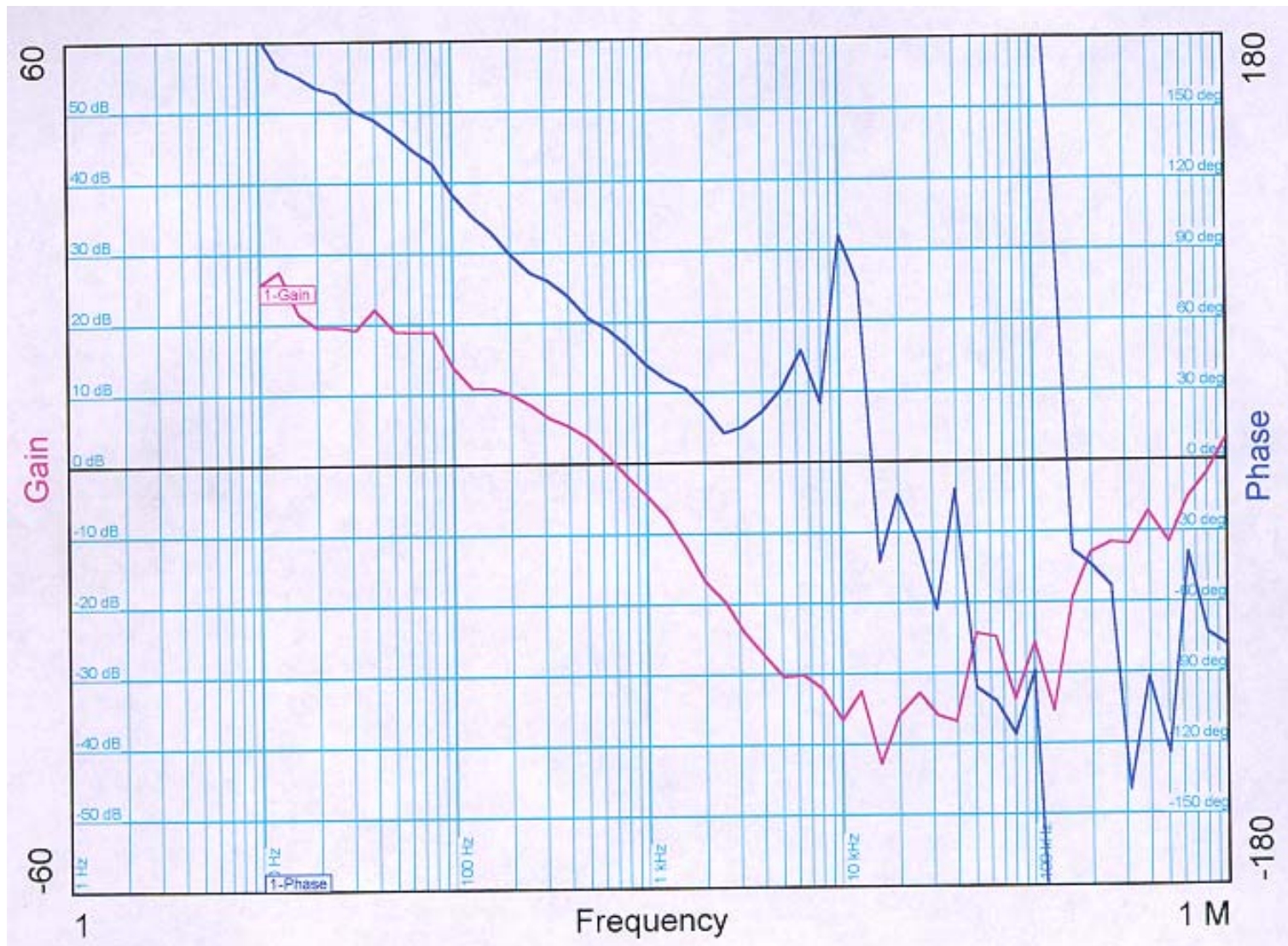


Figure 4. Phase and gain response vs. frequency of the controller at -185 °C.